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CORPS OF ENGINEERS, U. S. ARMY

FUNDAMENTAL CONCEPTS AND TERMS IN GEOCRYOLOGY
(PERMAFROST STUDIES)

OSNOVNYYE PONYATIYA I TERMINY GEOKRIOLOGII
(MERZLOTOVEDENIYA)

V. A. Obruchev Institute of Geocryology
Academy of Sciences of USSR

TRANSLATION NO. 28

:ic Construction and Frost Effects Laboratory
_. S. Army Engineer Division, New England
Waltham, Mass.

for

Office of the Chief of Engineers
Civil Engineering Branch
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Izdatel'stvo Akademii Nauk, 1956
(Academy of Sciences of USSR)

Translated from the Russian by Orest Popovych
Massachusetts Institute of Technology

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PREFACE TO TRANSLATION

For many of the concepts and terms defined herein, fairly literal translation has been deliberately adopted, even though possibly awkward, in order to minimize distortion of the meaning.

FOREWORD

The present project on basic terms of geocryology has been compiled by the Commission on Terminology of the V. A. Obruchev Institute of Geocryology, Academy of Sciences, USSR.

The work of the Commission on Terminology consisted of two phases: the first (from 1950 to 1953, Prof. P. I. Koloskov presiding), devoted to the compilation of existing definitions and terms of geocryology and their listing; the second (P. F. Shvetsov, corresponding member of Academy of Sciences, USSR, presiding), in which the existing terms and definitions were considered and criticized, new concepts and terms brought forth; the latter, after being discussed by the editorial and the terminological committees, are published in the present edition.

The purpose of this edition is to subject the proposed terminology of geocryology to the broadest discussion and criticism and to arrive at definite conclusions.

It is desired that persons participating in the discussion express themselves quite definitely concerning the expediency of the introduction of the various concepts and terms, and also whether the proposed terms reflect fully and correctly the phenomena and processes in the freezing, frozen, and thawing soil layers. It is also desired to introduce concrete and well-founded suggestions in regard to the improvement of the text of the various published and suggested terms and definitions.

Organizational Committee on the Convocation of the Meeting

December 1955.

FUNDAMENTAL CONCEPTS AND TERMS IN GEOCRYOLOGY

(STUDY OF PERMAFROST)

Prior to the revolution the study of the frozen zones of the earth's crust took place as part of the process of development of the mining industry, agriculture, and the construction and exploitation of the Eastern Siberian and Far East railroads. Therefore it could not avoid including in its terminology professional, often descriptive, words and expressions of prospectors, miners and agrarian colonists. Mining and railroad engineers, agronomists, soil technologists and meteorologists, coming in contact with permanently frozen rock layers and soils, and studying the conditions of stratification, state, peculiarities of composition and the structure of frozen subsoil, utilized these local professional terms, often without even giving any thought to their logical and physical meaning. If one considers that the knowledge of frozen soils and rock beds was formulated without a systematic participation of such Russian centers of learning as the Academy of Sciences, the Geographical Society and the Geological Committee in their compilation, analysis and generalization, it becomes clear why, in the terminology of the study of frozen zones of the earth's crust, there was, and remains, much vagueness and disagreement.

The adopted concepts and proposed terms were in contradiction with the general grammatic structure of Russian, with logic, and with fundamental scientific concepts of terms which have been defined and introduced into science by prominent scientists. This contention is supported by the following facts.

In the well-known expressions ''icy soil'' (A. F. Middendorf), ''permanently frozen soil'' (L. A. Yachevsky), and ''permanent soil frost'' (M. I. Sumgin), the word ''soil'' has an entirely different meaning as compared with that given to it by the founder of soil technology, V. V. Dokuchaev. From the definition of the scientific concept of ''soil'' it follows that soil cannot be frozen for many years, much less so permanently. Therefore neither Yachevsky nor Sumgin can have it (soil) in mind. Their word ''soil'' expresses the same concept which V. V. Dokuchaev and the prominent geologist academician A. P. Pavlov denoted by the term ''grunt''[1] (from the German der Grund) or subsoil, i.e. soil foundation.

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[1] Editor's note: The Russian word ''grunt'' is usually better translated as ''soil'' in English but often may mean ''ground.'' Many translations err in this respect. The Russian ''pochva'' is used for ''topsoil'' or ''surface soil'' and ''grunt'' for ''subsoil,'' in situ or as a test sample, i.e. ''soil'' in the engineering sense.

The disagreements in the interpretation and definition of the concepts ''frozen soil,'' ''frozen rock layer,'' ''frozen ground'' have as yet not been outlived. The founder and leader of the Soviet school of permafrost technologists, M. I. Sumgin, assumed that subzero or zero temperatures were the only characteristics of frozen soil and rock layers. This contention of M. I. Sumgin had been opposed even before and is now unacceptable to the majority of permafrost technologists.

Fundamental physical and physico-chemical phenomena, the significance of which helps to solve many structural-engineering, agrotechnical, geochemical and geomorphological problems, are especially connected with processes of uneven cooling and freezing, as well as heating and thawing of wet and water-bearing clays, granular soils, and rock layers. Thermal changes -- the freezing and thawing of soils and rock beds -- cause physico-chemical processes, which are very complex with respect to the nature and conditions of their development, mechanical stresses and movement of liquid and solid particles in these systems.

It is clear that water-free soils and bed rock which do not freeze at any temperature are theoretically conceivable. In practice, soils and bed rock containing only hygroscopic moisture firmly bound to the mineral particles can be considered dry and not freezable under natural conditions. If soils and rock beds contain not only hygroscopic moisture but also loosely-bound as well as free (gravitational) water, they will freeze at least partially, at -0.05 C. Such soils and rock beds, if at zero or subzero temperature and with the presence of ice (the latter in pores, crevices and other locations peculiar to soils and rock layers) can be considered as frozen. This was the opinion of A. I. Voyeykov. N. I. Tolstikhin and N. A. Tsytovich agree with him. The latter considers frozen ''such rock beds and soils, which have zero or subzero temperature and in which at least a part of the water is frozen.'' In the absence of ice from soils and rock layers, the zero or subzero temperature alone makes it permissible to call them <u>frosty.</u>

It is well known that concepts such as ''the zone of the earth's crust, represented by frozen and frosty rock beds,'' ''layer, or stratum of frozen rock beds,'' as well as the concept ''frozen soil,'' have been denoted and are still denoted by many by the expression ''frozen state.'' But the use of this expression as a scientific term has proved to be inexpedient because the investigators themselves have endowed it with a multitude of meanings, and it is well known that the lack of a single meaning is the greatest deterrent against inclusion of a word or expression among scientific terms. One must take into account that the expression ''frozen state'' has been endowed with various meanings within one and the same

branch of studies, M. I. Sumgin has equated the expressions ''permanently frozen soils'' and ''permanent frozen state of the soil.'' Other frozen-soil technologists have acted in a similar manner.

I. Ya. Baranov (1932) and later N. I. Tolstikhin (1941) have used the term ''permafrost'' to denote the phenomenon of cooling of rock layers to a point when the natural water occluded in them crystallized. S. G. Parkhomenko (1936) proposed that the word ''permafrost'' describe a process. D. B. Redozubov went even further in divorcing the word ''permafrost'' from the concept of ''layer or stratum of frozen rock beds,'' by calling permafrost a negative temperature field (1946) An extreme expression of this tendency is the recent remark of S. G. Boch: ''permafrost is the subzero temperature of the soil.''[1]

It proved possible to denote by the word ''permafrost'' four entirely different meanings because this everyday word is a noun derived from an adjective (permanently frozen), which is divorced from the object proper (its physical nature) just as, for instance, the word ''darkness'' has no exact physical meaning. M. V. Lomonosov, A. F. Middendorf and L. A. Yachevsky, in setting down the foundations of study concerned with the permanently frozen zone of the earth's crust, did not use the word ''permafrost''; it appeared and existed for the first time in the jargon of gold prospectors and settlers of Eastern Siberia and the Far East.

In 1753 M. V. Lomonosov formulated the scientific concept of a spherical shell consisting of the various layers of the atmosphere, regions and whole zones of the earth's crust as well as oceans, whose distinguishing characteristics are the subzero temperature of the medium and the presence or the possibility of existence of snow and ice.

One hundred and seventy years after its appearance in science this concept of a sphere of low temperature, snow and ice surrounding the earth was developed and made more precise by A. B. Dobrovolsky and expressed in one word ''cryosphere'' (1923). Later the cryosphere concept was expanded by V. I. Vernadsky, one of the initiators within the Academy of Sciences of USSR of a special scientific institution whose aim it is to investigate broad regions of the cryosphere. These are the zones of the earth's crust represented by layers with characteristics peculiar to the cryosphere: subzero temperatures and presence of ice in pores, crevices and other locations within rock layers. According to V. I. Vernadsky the cryosphere is the earth's thermodynamic shell, a shell of specific

[1] Handbook of Methods of Study and Geological Photography of Quarternary Deposits, Part 2. Gosgeoltekhizdat (State Geol. Tech. Publish.), Moscow 1955.

''dynamic physico-chemical equilibria, tending toward a stable state, which is constantly disrupted by the intrusion of forms of energy foreign to the given dynamic equilibrium.''[1] The cryosphere, like the biosphere, consists of parts of three geospheres: the troposphere (lower part of the air geosphere), hydrosphere and lithosphere (basically erosion crusts).

Starting with this concept of a cryosphere, that zone of the earth's crust which consists of permanently frozen and frosty rock beds can be called the frozen zone of the lithosphere (according to N. I. Tolstikhin in 1935 and 1941), or briefly cryolithozone. The Greek word ''cryos'' has two meanings: cold (frost) and ice, which underlines the dependence of the solid state of water substance upon a definite temperature.

Similarly the word ''permafrostology'' does not reflect the actual content of that strongly developed branch of natural sciences which it denotes. In actuality M. I. Sumgin in 1940 called permafrostology ''a study of the permanently frozen state and frozen ground,''[2] whereas today, permafrost technologists investigate not only frozen ground and ''permafrost,'' but also study the following:

1) The physico-geographic and geological conditions of heat exchange in the lithosphere system (soil and atmosphere), the processes of freezing and thawing of the earth's crust, regularity of development and growth of zones of frozen soil and rock beds -- cryolithozones;

2) The peculiarities of composition, structure, formation and properties of freezing, frozen and thawing soils and bed rock;

3) The physico-geological, geomorphological, and hydrogeological phenomena connected with the processes of freezing and thawing of soils and bed rock; and

4) Means of directing processes of thermal and mechanical interaction of freezing, frozen, frosty and thawing soils and bed rock with the results of human activity (construction, mining, plowfields, cultivation of plants, etc.).

The above and other inexactitudes in meaning and definitions and the gross contradictions between concepts and terms have caused several members of the V. A. Obruchev

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[1] V. I. Vernadsky, Selected Writings, vol. 1, p. 62, Acad. Sci. USSR Publ., 1954.

[2] M. I. Sumgin, General Permafrostology, Acad. Sci. USSR Publ., p. 3, 1940.

Institute on Permafrostology of the Academy of Sciences, USSR, to study the terminology, and to formulate exact concepts and definitions. A terminological commission was formed to support and develop individual efforts.

As a result of the work of the terminological commission of the Institute a catalog of the basic scientific terms used in the study of frozen zones of the earth's crust was compiled, and the definitions of concepts denoted by these terms were given.

The basic concepts and terms proposed by the terminological commission were analyzed by its members and discussed in special sessions of the editorial board. The faculty council of the Institute considered these terms to be fundamental for scientific papers submitted for publication, and simultaneously recommended their broad discussion in order to make them more exact and to develop the concepts themselves. They are being published with this in mind with the hope of response from the broad scientific community.

Chairman of the Commission on Terminology of the
V. A. Obruchev Institute on Permafrostology,
Corr. Memb., Acad. Sci. USSR, P. F. Shvetsov

30-12-55.

Catalog of Basic Terms in the Study of Frozen Zones of the Earth's Crust

Code	Concept or Term	Definition of Concept or Term	Nonrecommended Concept or Term
1	Cryosphere	In the thermodynamic sense, a separate shell of the earth, including definite regions of the atmosphere, hydrosphere and lithosphere; the peculiar characteristic of the cryosphere is its subzero temperature (possibility of existence or presence of ice).	
2	Geocryology (study of permafrost)	Study of the laws governing freezing and thawing of the earth's crust, development and expansion of zones of frozen soil and rock beds, peculiarities of their composition, structure and properties, accompanying processes as well as interaction with the results of the productive activity of man.	Cryopedology
3	Zones of frozen rock layers (cryolithozones)	Special regions or parts of the cryosphere represented by frozen soils and rock layers.	Region of permafrost
	a) Zone of seasonally frozen soils (seasonal cryolithozone)	The zone of seasonally frozen soils over unfrozen subsoil.	Seasonally frozen state
	b) Zone of perennially frozen rock layers (perennial cryolithozone)	The zone of lithosphere under seasonally thawing soil, remaining uninterruptedly frozen throughout several (not less than three) years.	Permafrost, perennial frozen state
4	a) Discontinuity of frozen rock layers (cryolithozones) along the vertical	Interbedding along the vertical of frozen and unfrozen rock layers and soils.	Stratified frozen state
	b) Discontinuity of frozen rock layers (cryolithozones) along the horizontal	Peculiarity of geographic distribution of frozen rock layers, soils (cryolithozones), manifested by the presence of regions without frozen rock layers and soils among areas with rock layers and frozen soils.	

Code	Concept or Term	Definition of Concept or Term	Nonrecommended Concept or Term
5	a) Formation of zones of frozen rock layers and soils (cryolithozones)[1]	Appearance, increase in size, lowering of temperature, increase in surface and decrease in discontinuity of frozen layers.	
	b) Degradation of zones of frozen rock layers (cryolithozones)	Decrease in size, increase in temperature, decrease in area of zones and increase of discontinuity of frozen layers.	Degradation of the frozen state
6	a) Seasonally freezing layer (seasonally frozen layer)	Layer of soil, or rock, which freezes during the cold period of the year, over unfrozen subsoil.[2]	Seasonal frozen state
	b) Seasonally thawing layer (seasonally thawed layer)	Layer of soil, or rock, thawing during the warm period of the year, over perennially frozen subsoil.[3]	Acting layer and active layer
7	Freezing	Physical processes expressed by the advance and expansion of the boundary of the frozen condition of soils and rocks.	
8	Thawing	Physical processes expressed by the advance and the expansion of the boundary of thawed condition of soils and rocks.	Unfreezing
9	Layer with annual temperature changes	Upper layer of the earth's crust whose soils and rocks experience annual temperature changes.	
10	Stratum of isothermal heat exchange[1]	Rock or soil layers whose zero or subzero temperature is constant during certain time periods, controlled by the crystallization of water or thawing of ice in the course of freezing or thawing.	Zero curtain, phase curtain

[1] No final form accepted.

[2] The extent of the seasonally-frozen layer depends upon the heat losses of the soil.

[3] The extent of the seasonally-thawed layer depends upon the heat supplied to the upper strata of the earth's crust.

Terms (cont'd)

Code	Concept or Term	Definition of Concept or Term	Nonrecommended Concept or Term
11	Geothermal level of heat exchange between the soil and the atmosphere[1]	Index of transient equilibrium in the thermodynamic interaction between the earth's crust and the atmosphere, manifested by the zero temperature of rock beds at the bottom of the layer having annual temperature fluctuations.	
12	Cryogenesis	Combined action of the physical, chemical and mineralogical processes changing and transforming soils and rock layers of the erosion crust as well as of the hydrosphere at subzero temperatures.	
13	Cryogenic phenomena	Peculiar physico-geological phenomena arising on freezing and thawing or on changes in the subzero temperature of soils and rock layers, as well as of water reservoirs and water ducts.	Physico-geological phenomena of the frozen state
	a) Thermokarst	Phenomenon of irregular settling and cave-in of the soil and its underlying rock layers as a result of thawing of subterranean ice.	Frozen state caves, polar caves
	b) Solifluction	Phenomenon of slow downslope flow of thawed soils or rock layers on inclined slopes arising under the influence of periodic freezing and thawing, the action of force of gravity, migration of moisture and other processes.	
	c) Layer of ice	Layer of freezing water or of water-soaked snow on the surface of the ice covering rivers, lakes or ice fields of other origins.	
	d) Hydroeffusion	Ice field cover, usually of stratified ice, arising in wintertime as a result of successive freezing of layers of ground water or water from an aquifer, flowing out on the surface.	Ice scale, layer of ice, icing

[1] No final form accepted.

Code	Concept or Term	Definition of Concept or Term	Nonrecommended Concept or Term
14	Subterranean ice	Ice contained in frozen soils and rock beds; this enters into the composition of the earth's crust both in monomineral rocks as well as in polymineral rocks.	Mineral ice
15	Frozen soils and rock beds	Soils and rock beds having a zero or subzero temperature, in which at least part of the contained water has frozen, i.e. has turned into ice, cementing the particles.	Frozen state
16	Frosty soils and rock beds	Soils and rock beds with a subzero temperature, not containing any ice.	Dry frozen state
17	Thawed soils and rock beds	Thawed or thawing soils and rock beds.	
18	Unfrozen soils and rock beds	Soils and rock beds having a positive temperature for several years.	
19	Components of frozen soils and rock beds	1) Solid: Mineral, organic, or mineral-organic framework 2) Solid: Cryogenic minerals (ice, cryohydrates, crystal hydrates) 3) Liquid 4) Gaseous	
20	Cryogenic structure	Structure of frozen rock beds determined by the size, relative amounts, form and orientation of the component parts (mineral framework, ice crystals, liquid films and nuclei, gaseous occlusions and pores).	Frozen structure
21	Cryogenic texture	Texture of frozen rock beds arising in the course of freezing.	Frozen texture
22	Total moisture of frozen soils, grounds and rock beds	Total content of ice and water in frozen soils and rock beds.	
23	Iciness of frozen soils and rock beds	Ice content in soils and rock beds.	

Terms (cont'd)

Code	Concept or Term	Definition of Concept or Term	Nonrecommended Concept or Term
	a) Ice-concrete	Ice cementing soils and weathered rock beds without appreciable disruption of the particles of the mineral structure.	
	b) Segregated ice: striations, prisms, etc.	Ice formed in soils and weathered rock beds as a result of crystallizational differentiation during freezing.	
24	Porosity of frozen soils and rock beds	Volume of the structural pores occupied by gases, liquid moisture, ice and cryogenic materials.	
25	Cryogenic processes	Physical, physico-chemical and physico-mechanical processes in the freezing and thawing of soils and rock beds.	
26	Cryogenic minerals	Minerals existing at subzero temperatures (ice, crystal hydrates).	
27	Migration (movement) of moisture during freezing	Displacement of moisture in the liquid and vapor phase in the process of freezing of soils and rock beds, as well as during the period of their frozen condition.	
28	Heave (on freezing)	Elevation of the surface of soils and rock beds, caused by a change in their volume on freezing as a result of spreading of the structural particles by ice crystals formed from water at the freezing layer, water migrating from unfrozen layers, or water fed under pressure.	
29	Settlement on freezing	Decrease in volume of rock beds on freezing.	
30	Freezing pores	Pores formed in soils and rock beds in the course of freezing as a result of their uneven change in volume.	
31	Settlement on thawing	Vertical settlement of soils and rock beds caused by decrease in volume on thawing.	

Code	Concept or Term	Definition of Concept or Term	Nonrecommended Concept or Term
32	Subsidence on thawing	Rapid local settlement of soils and rock beds on thawing caused by a radical change in composition.	
33	Adfreezing	Process of the appearance and development of bonds between freezing moist soils and rock beds and the surface of any body in contact with them.	
34	Adfreeze resistance, or the strength of adfreeze bond.	Resistance of soils and rock beds frozen to some body (for instance a foundation) to displacement along a surface of the latter.	Forces of adfreezing[1]
35	Instantaneous resistance of frozen soils and rock beds	The greatest resistance of frozen soils and rock beds to disruption corresponding to a rapid (theoretically with the speed of sound) application of stress; in practice it is very close to temporary resistance.	
36	Finite long term resistance of frozen soils and rock beds	Resistance of frozen soils and rock beds to disruption on infinitely slow application of stress, i.e. a degree of stress up to which no disruption takes place with practically unlimited duration of load application.	

[1] This term should be taken to mean reaction forces arising in the ground frozen to some body along the surface of that body as a result of external forces.